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(54) Abstract Title
Scribing and breaking semiconductor substrates

(57) A hard-to-scribe substrate 4 is lapped to a thickness suitable for later cleaving and on the surface of the substrate selected for scribing, a non-ductile material such as a dielectric scribe facilitation layer 2 is grown or deposited. This layer's hardness and thickness are selected to be softer than the substrate and to accept a clean scribe line. Alternately, or in conjunction, a second non-ductile layer such as dielectric break facilitation layer is grown or deposited on the side of the hard-to-scribe substrate other than the one selected for scribing. This layer's thickness and hardness are selected to put the scribing surface in an optimal state of tension for clean break propagation. An optional layer of metal 6 is placed over the surface to be scribed. This layer serves to dissipate heat generated from die separation and shield the cutting tool from piezoelectric discharge. The layer 2 may be a nitride, an oxy-nitride or an oxide.

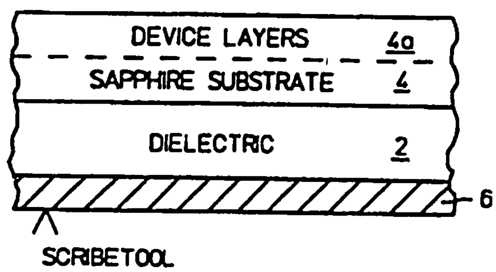

Figure 1A

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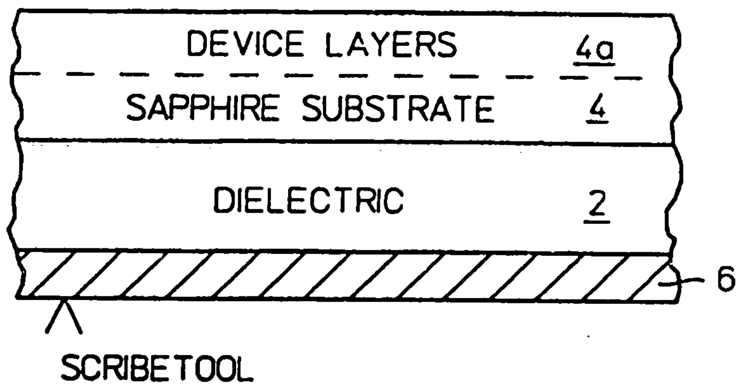

Figure 1A

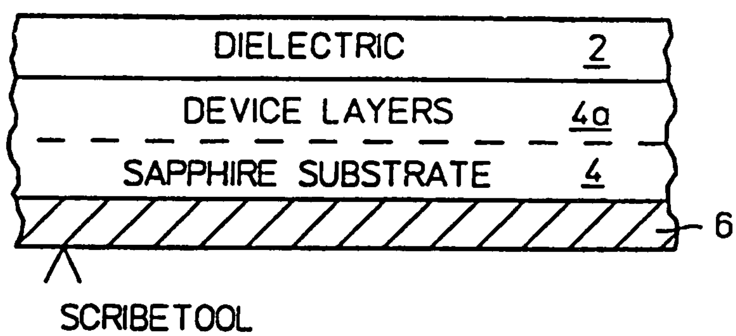

Figure 1B

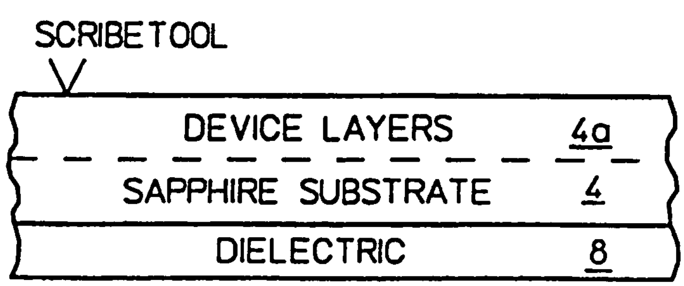

Figure 1C

SCRIBE AND BREAK ON THE "COAT" SIDE

10	FABRICATE A WAFER OR A PLATE MADE OF THIN DEVICE LAYERS OVER A THICK SUBSTRATE
20	PROCESS THE RESULTING STRUCTURE INTO MANY CONTIGUOUS DEVICES.
30	THIN THE SUBSTRATE DOWN TO A THICKNESS SUITABLE FOR LATER BREAKING THE WHOLE STRUCTURE INTO INDIVIDUAL DEVICES BY PROCESSES SUCH AS (BUT NOT LIMITED TO) GRINDING, LAPPING, ETCHING, OR LIFTING ON THE NON-DEVICE SIDE. 30 TYPICALLY OCCURS BETWEEN STEPS 20 AND 40A, BUT MAY OCCURS ANYWHERE AFTER STEP 10 AND BEFORE STEP 60.
40A	COAT THE DESIRED SIDE OF THE STRUCTURE WITH A DIELECTRIC (OR OTHER NON-DUCTILE MATERIAL) SCRIBE AS FACILITATION LAYER OF SUITABLE THICKNESS AND OF HARDNESS SUCH AS TO PROMOTE LATER AT SCRIBING A GOOD SCRIBE LINE AND AN EASY AND CLEAN BREAK INITIATION. THIS "COAT" CAN BE FABRICATED BY PROCESSES SUCH AS (BUT NOT LIMITED TO) GROWTH, OR DEPOSITION, OR BONDING, OR SPINNING.
50A	OPTIONALLY, OVERLAY THE "COAT" WITH A METALLIC LAYER OF GOOD DUCTILITY, OF GOOD ELECTRICAL CONDUCTIVITY, AND OF GOOD THERMAL CONDUCTIVITY.
60A	SCRIBE AND BREAK THE STRUCTURE INTO INDIVIDUAL DEVICES BY SCRIBING THE "COATED" SIDE.

Figure 2A

SCRIBE AND BREAK ON THE OPPOSITE SIDE

10	FABRICATE A WAFER OR A PLATE MADE OF THIN DEVICE LAYERS OVER A THICK SUBSTRATE
20	PROCESS THE RESULTING STRUCTURE INTO MANY CONTIGUOUS DEVICES.
30	THIN THE SUBSTRATE DOWN TO A THICKNESS SUITABLE FOR LATER BREAKING THE WHOLE STRUCTURE INTO INDIVIDUAL DEVICES BY PROCESSES SUCH AS (BUT NOT LIMITED TO) GRINDING, LAPPING, ETCHING, OR LIFTING ON THE NON-DEVICE SIDE. 30 TYPICALLY OCCURS BETWEEN STEPS 20 AND 40A, BUT MAY OCCURS ANYWHERE AFTER STEP 10 AND BEFORE STEP 60.
40B	COAT THE DESIRED SIDE OF THE STRUCTURE WITH A DIELECTRIC (OR OTHER NON-DUCTILE MATERIAL) BREAK INITIATION LAYER OF SUITABLE THICKNESS AND OF HARDNESS SUCH AS TO PUT THE OTHER SIDE OF THE IN AN OPTIMAL STATE OF TENSION CONDICIVE TO PROMOTING LATER AT SCRIBING AN EASY AND CLEAN BREAK INITIATION. THIS "COAT" CAN BE FABRICATED BY PROCESSES SUCH AS (BUT NOT LIMITED TO) GROWTH, OR DEPOSITION, OR BONDING, OR SPINNING.
50B	OPTIONALLY, OVERLAY THE NON-COATED SIDE WITH A METALLIC LAYER OF GOOD DUCTILITY, OF GOOD ELECTRICAL CONDUCTIVITY, AND OF GOOD THERMAL CONDUCTIVITY.
60B	SCRIBE AND BREAK THE STRUCTURE INTO INDIVIDUAL DEVICES BY SCRIBING THE SIDE WHICH DOES NOT HAVE THE NON-DUCTILE "COAT" AND WHICH MAY OR MAY NOT HAVE A METALLIC SURFACE LAYER.

Figure 2B

SCRIBING MATERIALS

This invention is related to the scribe and break of hard-to-scribe materials, more particularly in the manufacturing of semiconductor devices. In particular, the invention is directed towards separating devices grown on a monolithic substrate.

Blue/green light emitting devices are thin (~1 - 10 micrometers) GaN-based compound device structures of hexagonal crystalline symmetry ("wurtzite") grown on a thick sapphire substrate (~100 - 500- micrometers - thick, disk-shaped, substrate wafers that have diameters between 50 to 150 millimetres). The devices are often square-shaped, typically 200 - 500 micrometers on a side. There are therefore many such contiguous, individual devices fabricated on one substrate. Separation of the devices (i.e., singulation of the "wafer" into individual "dice") is very difficult because GaN and sapphire are almost as hard as diamond, and because sapphire's natural cleave planes are not at right angle to the surface. Thus, the singulating break planes through the wafers are not smooth, flat and vertical, which will impact device performance and reliability.

One prior art method to separate the devices is to saw the devices apart. Sapphire and GaN-based compounds are so hard that the saw blade have impractically short life times for sawing small devices (typically <250 linear centimetres). In addition, sawing requires wide kerfs, the amount consumed from sawing, ~ > 150 micrometers. Sawing also causes excessive chipping and undesirable cracks that propagate into the active region of the devices, resulting in poor performance and reliability.

Another prior art method is to laser cut the die apart. Unfortunately, sapphire requires very short lasing wavelengths (< 230 nanometers), so that laser use results in too

much heat. The dice are subject to undesirable thermal expansion. And, the separation quality is not very much superior to the one obtained by sawing.

In another prior art method, "scribe and break", a scribe line is used to define the separation of the dice and the dice are separated along this line by propagation of a break initiated by the scribe mark. This method is barely adequate with respect to throughput and cost because the "street" between the dice is on the order of 50 - 150 micrometers, a significant amount of space on a wafer. Also, on such hard surfaces a scribing tool typically has a useful life of less than 500 linear centimeters.

All of the aforementioned prior art methods consume expensive substrate material and generate break surfaces of inadequate or barely adequate smoothness. A method that efficiently uses costly, hard-to-scribe substrates is desirable. It would be a further cost and throughput benefit if the method prolonged cutting tool life. Finally, a method that generates clean, smooth, vertical break planes would improve the performance and reliability of the final devices.

Similar problems are encountered when trying to separate devices in other hard-to-cleave material systems, such as GaN-based devices grown on GaN substrates (or other substrates than sapphire); some kinds of glasses used in the manufacturing of flat panel displays; or other glass- or quartz- based devices (wafer-bonded night-vision systems, for instance). Other problem systems are hard-to-scribe semiconductors such as gallium phosphide (GaP) or compound semiconductors such that the substrate or wafer layer where the scribing is initiated is of a different material system than for some other layers in the device.

A hard-to-scribe substrate, having a device surface, is thinned (for example, by processes such as lapping, grinding, etching, lift-off, etc.) to a thickness appropriate for later cleaving. On either surface of the substrate, a layer of dielectric or other non-ductile material ("coat") is grown or deposited.

When scribing is done on the surface of this "coat", the "coat" material plays the role of a scribe facilitation layer: it is selected to be softer than the substrate and to accept a clean scribe line. Its thickness is optimized to generate good break propagation. An optional layer of metal is placed over the scribe facilitation layer. This metal layer serves to dissipate heat generated from die scribing and separation, as well as to shield the cutting tool from piezoelectric discharge.

When scribing is not done on the surface of the "coat", but instead on the other side of the substrate, the "coat" thickness and hardness are selected to put the scribing surface in an optimal state of tension for clean break propagation. An optional layer of metal is placed over the surface to be scribed. This metal layer serves to dissipate heat generated from die scribing and separation, as well as to shield the cutting tool from piezoelectric discharge.

Figures 1A-C illustrate cross-sections of a wafer having improved scribe and break.

Figures 2A - 2B illustrate process flow charts for the present invention.

Figures 1A-C illustrate cross-sections of a wafer having improved break propagation. In Figure 1A, a dielectric layer 2 is grown on the thinned backside of a hard-to-scribe substrate 4, such as sapphire or gallium nitride (GaN) or gallium phosphide (GaP). In Figure 1B, the dielectric "coat" is deposited over the device side 4a of the sapphire substrate. In both Figures 1A and 1B, an optional metal layer 6, such as aluminum, is deposited over the dielectric 2. In both Figures 1A and 1B, the scribing occurs on the thinned substrate side, eventually coated with metal. An optional second dielectric layer and second metal layer may be deposited on the opposing side (not shown). In Figure 1C, a single dielectric layer 8 is deposited on the thinned side, while the scribing occurs on the device side, which remains uncoated.

Whenever the scribing is done on the "coat" side, the "coat" plays the role of a scribe facilitation layer: it is selected to be an easily cleavable material softer than sapphire, such as silicon dioxide (SiO_2). As a result, the scribe line on the "coat" material is cleaner and better defined than on sapphire. A clean break initiation results in good break propagation for breaks through the hard materials. In addition, the break is further helped by subjecting the wafers to a stress that is conducive to clean break propagation. As a result, the scribing tool life is prolonged and leads to yield improvements and reduced fabrication costs.

The optional metal layer 6 serves to lubricate the die cutting tool to cushion the impact of the tool on the substrate, and to dissipate heat. Heat generated from the cutting process contributes to tool wear which degrades the scribing quality. In addition, this layer acts to shield the tool from piezoelectric discharge that will also increase wear and tear.

While the scribe facilitation layer 2 may be aluminum nitride, alumina, silicon nitride, silicon oxy-nitride, or comparable dielectric or non-ductile layer, silicon oxide or silicon dioxide are preferred. The hard-to-scribe substrate 4 may alternatively be a

semiconductor, i.e. GaP, silicon, silicon-carbide, or GaN, a spinel, a glass, i.e. G7, or a large plate of quartz.

Figures 2A and 2B illustrate process flow charts directed towards the present invention. In step 30, the back side of the substrate is lapped to an approximate thickness ~ 50 - 150 micrometers for most material systems. In step 40, a dielectric layer, having thickness typically between 5 - 1000 nanometers, is grown over the desired side of the substrate. The dielectric layer may be deposited through sputtering, evaporation, ion beam deposition, chemical vapor deposition (CVD), plasma enhanced CVD, or even spun-on glass. In step 50, the optional metal layer is deposited on the surface to be scribed. In step 50, the wafer structure is scribed, and then broken along the scribe lines.

The dielectric or non-ductile layer is preferably deposited onto the selected surface such that surface to be scribed is under tension. This reduces the "street" required between the dice by promoting cleaner break propagation and by reducing the die's edge chipping.

The main difference between processes shown in Figures 2A and 2B is over the role of the dielectric or non-ductile layer ("coat"). In Figure 2A, the "coat" is relatively soft (i.e., silicon dioxide) and primarily allows for clean scribing and break initiation (scribe facilitation): putting the scribing surface under proper tension is a secondary consideration. In Figure 2B, the primary purpose of the "coat" is to put the opposite, scribing surface under proper tension for optimum break propagation after break initiation (break facilitation): the material can then be fairly hard (i.e., silicon nitride), since the scribing tool never makes contact with it.

Finally, it is possible to combine processes shown in Figures 2A and 2B, by coating the surface to be scribed with a softer, more cleavable material and coating the other side with a harder material; the thicknesses of the softer "coat" material and of the

harder "coat" material will be optimized respectively for break initiation (scribe facilitation) and break propagation (break facilitation).

Claims

1. A method for scribing and breaking comprising the steps of:
thinning a hard-to-scribe substrate.
applying a first non-ductile layer over one of the two sides of the thinned hard-to-scribe substrate, the substrate having a scribing side and a non-scribing side;
scribing scribe lines on the scribing side of hard-to-scribe substrate; and breaking the substrate along the scribe lines.

2. A method as defined in claim 1, wherein the hard-to-scribe substrate is selected from a group comprising sapphire, silicon, silicon-carbide, gallium nitride (GaN), gallium phosphide (GaP), glass, and quartz.

3. A method as defined in claim 1 or 2, wherein the first non-ductile layer is selected from a group comprising aluminium nitride, alumina, silicon oxide, silicon dioxide, silicon nitride, and silicon oxy-nitride.

4. A method as defined in any preceding claim, further comprising the step of overlaying the scribing side of the hard-to-scribe substrate with a metal layer prior to the step of scribing.

5. A method as defined in any preceding claim, further comprising the step of placing a second non-ductile layer over the other of the two sides of the hard-to-scribe substrate.

6. A method as defined in claim 5, wherein the second non-ductile layer is selected from a group comprising aluminium nitride. alumina silicon oxide, silicon dioxide, silicon nitride, and silicon oxy-nitride.

7. A method as defined in claim 6, further comprising the step of overlaying the scribing side of the hard-to-scribe substrate with a metal layer prior to the step of scribing.

8. A method of scribing a material for subsequent breaching substantially as herein described with reference to each of the accompanying drawings.

The Patent Office

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Application No: GB 9804385.4 **Examiner:** C.D.Stone
Claims searched: All **Date of search:** 1 June 1998

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.P): H1K(KLX,KGD)

Int Cl (Ed.6): H01L

Other:

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
X	GB 2285333 A A.T.&T. (See steps 23,24,27 in Fig.1B)	1

X Document indicating lack of novelty or inventive step	A Document indicating technological background and/or state of the art.
Y Document indicating lack of inventive step if combined with one or more other documents of same category.	P Document published on or after the declared priority date but before the filing date of this invention.
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